Understanding the (mis)behavior of water contents in nominally anhydrous mantle minerals

EDWARD W. MARSHALL[1]*, JOHN C. LASSITER[1], JAIME D. BARNES[1]

[1] Department of Geological Sciences, The Unviersity of Texas at Austin, Austin, Texas, 78712, USA
(*correspondence: edmarshall4@utexas.edu)

In magmatic systems, water behaves as an incompatible species and therefore should be depleted in mantle peridotites during melting and enriched during metasomatism. Although some previous studies of nominally anhydrous mineral (NAM) water contents in peridotites have observed correlations with indices of metasomatism or melt extraction, in detail, these correlations are often inconsistent with predicted trends deriving from either process. For example, correlations between NAM water content and indices of metasomatism are often only observed in some minerals within a given suite of xenoliths even if all minerals have been affected by metasomatic processes. Similarly, correlations between NAM water content and indices of melt extraction result in significantly higher water contents than predicted by melting models using experimental constraints on water partitioning. Finally, although growth of hydrous minerals requires higher water activity than in anhydrous peridotites, no significant differences are observed in either NAM water content or water activity between hydrous and anhydrous xenoliths from individual localities or within a global compilation of mantle xenoliths.

We propose that the high diffusivity of water in mantle peridotites allows for equilibration of water activity in the mantle over geologic time, with water-rich (metasomatized) regions losing water over time, and water-poor (melt-depleted) regions gaining water via diffusion. This homogenizes water activity and obscures initial correlations between NAM water content and indices of metasomatism or melt extraction, explaining the inconsistencies described above. As a result of diffusive equilibration of water, variability in NAM water content in mantle peridotites is significantly reduced relative to the variability of similarly incompatible elements (e.g., Ce) in the same peridotites. For example, whereas the concentration of water in mantle-derived clinopyroxene spans ~1 order of magnitude, Ce concentrations in the same samples spans ~4 orders of magnitude. This difference in behavior explains why H_2O/Ce ratios in mantle peridotites are highly variable relative to those of basalts, and why H_2O/Ce strongly correlates with Ce concentration but not with cpx water content.